DOCUMENT RESUME

ED 042 600 SE 008 004

AUTHOR	DeRose, James V.
TITLE	Independent Study in High School Chemistry: A Progress Report.
INSTITUTION	Marple Newton School District, Newton Square, Pa.
PUB DATE	9 Jan 70
NOTE	29p.; Paper presented at the Annual Meeting of the National Science Teachers Association (18th, Cincinnati, Ohio, March 13-17, 1970)
EDRS PRICE	EDRS Price MF-$0.25 HC-$1.55
DESCRIPTORS	Academic Achievement, *Chemistry, Course Objectives, *Curriculum, Evaluation, *Independent Study, *Program Descriptions, *Secondary School Science

ABSTRACT

This is a progress report of an independent study program in chemistry at a senior high school. Currently in its fourth year of operation, the program is designed to provide students with individualized, self-paced instruction in college-preparatory chemistry. The author discusses the rationale for the program, the initial phases, the problems encountered and changes instituted each year, and the program as it is presently structured and operated. The establishment of a hierarchy of behavioral objectives and the procedures for evaluating student performance are presented. The report includes an analysis of data collected on the performance of students in both the independent study and the conventionally taught chemistry programs. The results indicate that the independent study students are better able to achieve and retain the processes, generalizations and hypotheses of chemistry than the conventional chemistry students. The report concludes with plans for the future development of the program. Bibliography. (LC)

ED042600

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL OFFICE OF EDUCATION POSITION OR POLICY.

1/9/70

Independent Study in High School Chemistry: A Progress Report

by
James V. DeRose
Head of Science Department
Marple Newtown School District
Newtown Square, Pennsylvania

The Independent Study Science Program at Marple Newtown Senior High School is currently in its fourth year of operation. Although the original plans for individualized self-paced programs in biology, chemistry and physics as reported earlier (1) have all been modified considerably during the past three years, only experience with the independent study chemistry program will be related at this time. The rationale, the initial program, the problems encountered and changes instituted each year, and the program as it is presently structured and operating will be discussed. In addition, an analysis of data collected on the performance of students in both the independent study and the conventionally taught chemistry programs will be presented and considered.

Evolution of the Program: The First Year

The independent study program is based on a belief and a hope: the belief that existing school organizational structures and teaching patterns inhibit the full exercise of students' potential for learning, and the hope that a modification can be devised that makes students' experience in learning how to learn whatever they need to learn the activity of prime importance.

SE 008 004

The ultimate goal of formal education is independence in learning on the part of the learner. As Piaget (2) has said: "The goal of education is not to increase the amount of knowledge but to create possibilities for a child to invent and discover, to create men who are capable of doing new things." Specifically, the independent study chemistry program is designed to provide students with the opportunity to learn on their own and in their own way whatever they would be expected to learn in the college preparatory chemistry course if they were enrolled in a class taught in the conventional manner.

Student selection procedures were designed purposely to give the program every advantage of succeeding. Teachers were asked to make confidential nominations of students who were relatively mature and self-disciplined. The student nominees were ranked on the basis of their Sequential Test of Educational Progress (STEP) scores in mathematics, science and reading.

The program was described in turn to the highest-ranked nominees and their parents until fifteen students were enrolled. They were told that the independent study students would be expected to direct their own learning with assistance from me as their teacher only when requested and that, henceforth, I would be known as their mentor to emphasize our new relationship. Each student with guidance from the mentor would be expected to develop a custom-tailored program which included as a minimum the major topics of the regular college preparatory chemistry course. They would be assigned to a laboratory and classroom for seven class periods each week just as the regular chemistry students are assigned. However, no teaching in the conventional sense

would take place. The mentor would advise and assist at his discretion and as requested by the student. It was fully expected that the independent study students would achieve an understanding of a larger number of topics and laboratory investigations, and in greater depth, than would be possible if they were bound to the pace of a conventionally taught class. In addition, each student would be free to exploit his own particular talents and interests in an area beyond the basic requirements of the course. Two of every three nominees invited found the opportunity interesting enough to accept.

When the independent study program went into operation, it soon became obvious that the description of the college preparatory chemistry course in terms of chemical topics to be understood was not very helpful - the expected breadth and depth of each topic could not be easily delineated for the students. This problem was solved by describing the expectations in terms of behavioral objectives in the Mager style (3). Subsequently, students received, as they were written, statements of what they should be able to do at the completion of their study of the topics in each chapter and the related laboratory work of the basic text and laboratory guide (4). The problems encountered in writing clear, unambiguous and significant behavioral objectives in chemistry, with particular reference to the laboratory, has been described by the writer elsewhere (1, 5). A major stumbling block to the implementation of this independent study program was eliminated when students were given behavioral objectives to guide them. Essentially, students knew the minimum competencies they were to acquire, all they had to do was plan

and do whatever was necessary to achieve them. Students in the conventionally taught chemistry classes were expected to achieve the same objectives.

The independent study students during the first year were required to take the same chapter, semester and final examinations as the other college preparatory chemistry students and on the same dates. At this time, however, none of the items on any of the examinations had a one-to-one correspondence with a specific behavioral objective. The examination items and the behavioral objectives in each case were related to the same body of chemistry but not related precisely to each other. The results on these examinations the first year indicated that the independent study students were learning more on their own than either the conventionally taught accelerated or regular students. The mean percentage of questions answered correctly on the chemistry final examination was 68 for the independent study students, 59 for the accelerated students and 40 for regular students in conventionally taught classes (Table 1). A detailed comparison of the achievement of independent study and accelerated conventionally taught chemistry students is made later in this paper.

As a result of the first year's experience, several new ideas and directions were evolved. In general, the independent study students could and did learn on their own; they did not need formal presentations by a teacher; they could read their text and conduct the laboratory investigations; and they consulted the mentor more or less only when they had a problem - one they were expected to describe clearly. (Since a complete description of the mentor's role and experience with independent study students has been previously reported (1), only brief references to this

important aspect of the program will be made in this paper.) Most of the independent study students enjoyed the freedom to plan and direct their own activities for learning. As a group, they were able to pace themselves with the students in the conventionally taught classes. On the other hand, although urged to do so, very few independent study students did more than was necessary to meet the basic requirements of the course; the difference between the rates of the fastest and slowest moving student was very small indeed. Since students had to take the examinations when scheduled, they worked in spurts, always more intensely as the day of the examination approached and less so after the examination had been taken. Very few attempted to achieve any objectives related to chapters beyond that of the next chapter to be examined. A majority of the students admitted that they did not learn what they were capable of learning in the time available. Something had to be done to make the program individualized and self-paced.

The Second Year

Sixteen students were enrolled in the independent study chemistry program in the second year. The selection procedures followed the first year were used the second year. Approximately 85% of the nominees who were invited accepted.

The mentor completed the task of writing a first draft of behavioral objectives for chemistry during the second year. Most of the objectives were revised several times in response to suggestions from students and teachers. Also, an initial attempt was made to arrange the objectives within chapters into a hierarchy reflecting the dependent and interdependent relationships. Students found the hierarchy useful as a guide to follow in planning their study sequences.

Table 1. Means* of regular, accelerated and independent study chemistry classes** for 1966-67, 1967-68 and 1968-69 on semester examinations (SE), final examinations (FE)*** and Differential Aptitude Tests (DAT) of Abstract Reasoning (AR) and Numerical Ability (NA).

Track	1966-67					1967-68					1968-69				
	Number of Students	SE	FE	DAT AR	DAT NA	Number of Students	SE	FE	DAT AR	DAT NA	Number of Students	SE	FE	DAT AR	DAT NA
Reg.	235	57	40	--	--	253	59	40	--	--	269	48	36	--	--
Accel.	15	79	59	89	93	23	75	57	92	93	26	63	48	90	93
I. S.	14	78	68	88	92	15	76	68	91	95	19	71	63	94	95

* All scores reported as the percentage of questions answered correctly.

** Accelerated students begin in the 9th grade the three-year college preparatory science sequence which regular students begin in the 10th grade. The independent study chemistry classes are composed of both accelerated and regular college preparatory students.

*** The same final examination was administered each year.

Again, the independent study student took the same examinations and at the same time as the conventionally taught chemistry student, but this year the examinations were composed of criterion test items which had a one-to-one correspondence with specific behavioral objectives. Furthermore, both the independent study and the conventionally taught students knew in advance which objectives would be assessed. In other words, students knew exactly which behaviors they would be asked to demonstrate. They did not know the specific criterion test item that would be used to determine whether or not they possessed the desired behavior, but they did know exactly which behaviors would be examined. All they had to do was to be sure they had acquired the behaviors specified.

As in the first year, the pace of most students was determined by the examination schedule; only a few students worked with behavioral objectives not scheduled to be examined. A majority of the students admitted that they were able to learn at a pace much greater than that set by the examination schedule of the regular classes in chemistry. This comment from one student was typical: "I just can't study a new topic until I've taken the examination on the last one. I'm afraid I'll forget what I learned earlier."

The solution to this problem was obvious. Since the rate at which students learn is a function of the examination schedule, it follows that the single examination for all students must be replaced by individual examinations for each student whenever he is ready. Only then could the student be "liberated" from the psychological block of not being able to concentrate on new material before he had been tested on the old.

Although the direction which should be taken was clear, the tasks of writing and revising the behavioral objectives, preparing a first draft of a hierarchy and writing just one criterion test items for each objective were so demanding in time, energy and thought that it was impossible to institute the change during the second year.

In spite of the fact that a majority of the independent study students, by their own admission, did not take advantage of the opportunity to pace themselves in line with their potential to do so, they did learn to do on their own what the behavioral objectives examined indicated they should be able to do in a relatively creditable manner. The mean percentage of questions answered correctly on the final examination was 68 for the

independent study students, 57 for accelerated students and 40 for regular students in conventionally taught classes (Table 1). The mentor's dissatisfaction with the independent study program at this stage centered largely on its inability to provide effective mechanisms to ensure maximum individualization and self-pacing for each student in terms of his potential.

The Third Year

The selection procedure used the first two years was followed to enroll nineteen students in the third year. All of the nominees who were invited accepted. The number enrolled was increased to test the upper limit in numbers which would still permit an effective communication between the students and the mentor.

An important change in the operation of the independent study chemistry program was made in the third year. Instead of examining independent study students as a group with the regular chemistry classes, each independent study student would be examined on each objective individually and only when the student himself said he was able to do what the objective said he should be able to do. If a student successfully demonstrated that he had acquired all of the behaviors described by the objectives of the course before June, he would be given his grade and credit for the course and be free to spend the rest of the time as he wished; however, no one would be permitted to progress at a pace less than that of the regular chemistry classes, but the mechanism for ensuring this minimum pace was not stated in the hope that it would not be necessary to take any action in this regard.

To institute this change in the program, a large number of criterion test items would need to be written for each objective so that students examined on the same objective on different days could be given different criterion test items. Six to ten criterion test items for each objective examined were written during the third year, but more will need to be written as the number of independent study students enrolled is increased.

So as not to delay their progress, I promised to read proposals for laboratory investigations, laboratory reports, administer criterion test items as requested and mark their papers as received. This was a mistake. I was not free, whenever I met my students during class time, to consult and work with them individually, gauge the status and needs of each student or to evaluate the program. Consequently, I decided that no reports or papers would be marked during class time; but students were promised that they could count on receiving their marked papers and reports the day after they were submitted. It soon became apparent that the promise to give students the criterion test item for each objective as requested had to be amended also. The mentor's time with students was hopelessly and needlessly fragmented and reduced in the process of distributing and receiving the criterion test items and response papers. This problem was solved by setting aside one day each week in which students could take the criterion test items they requested, and an additional day each week for students who had failed to do what they said they were able to do on a previous attempt.

Did independent study students take advantage of this opportunity to progress at their own rate? By their own

admission, only a few students were progressing as rapidly as they should--most of them were dragging their heels, although quite unintentionally. Several independent study students had to be placed on the same testing schedule as that of the regular classes because they could not discipline themselves to do what they had to do. It should be noted that the pace of the regular chemistry classes this year had been decreased intentionally over that of previous years to determine whether or not spending more time teaching each of the topics would increase the percentage of students achieving each of the objectives of the course. The independent study chemistry students, although the opportunity for individual progress rates was available, tended to adjust their individual progress rates downward in spite of the admonishments and concern of the mentor. Accordingly, as reported in Table 1, the mean scores on the final examination were also down from previous years: 63 for the independent study students, 48 for the accelerated students and 36 for the regular students.

These independent study students were unable, like their predecessors, to discipline themselves to do a job by a self-set schedule. One must face the fact that students being students (or people being people?) the assumption cannot be made that they will discipline themselves to do what needs to be done in the absence of either deadlines or of a policy that limits credit to those who do what needs to be done.

The student had been told that if he finished the prescribed course in less than one year he was free to do other things; he had not been told that he would have to continue until he finished the course before he would receive credit, regardless of

the time spent. One would assume, but cannot be sure, that this requirement would increase the self-discipline and drive of an individual. Since it is impossible in our school system to impose such a requirement at this time, it was necessary to devise and implement another procedure to ensure a more complete expenditure of each student's time and capabilities.

The Program Today

The selection procedure used the preceding three years was modified slightly to enroll independent study students for the fourth year. The nominations were solicited from teachers as before, but now the students to be invited were selected from the nominees at random. Thirty-eight students were enrolled. Approximately 91% of the nominees who were invited accepted. Two classes were organized, and another mentor was added to the program. The number enrolled was increased to meet the growing interest of students and to determine the nature of the problems that would be encountered in expanding the program with particular regard to facilities, equipment and staff.

By the end of the third year a complete set of 168 behavioral objectives for high school chemistry had been written and published (5). Experience in the preceding three years indicated that only a very few students could be reasonably expected to achieve all of these objectives within a school year. The practice of trying to achieve all of the objectives in order, following the hierarchy, meant that some topics introduced early were studied too intensively while many other topics such as electrochemistry, equilibrium, acid-base chemistry and kinetics were considered by only a few students or not at all. To correct

this imbalance and reduce the expectations for students to a reasonable level, the writer and two other chemistry teachers (6) made independent selections first and then together selected 86 behavioral objectives which we believed to be basic and of first order importance in achieving a broadly based understanding of chemistry. The chemistry course is now defined by this set of 86 basic behavioral objectives. The other 82 behavioral objectives are optional; students who wish to learn more are encouraged to achieve as many of them as they can.

The culmination of three years of work in writing and ordering behavioral objectives is summarized in the hierarchy chart of Figure 1. Each beginning independent study student now receives a complete set of 168 behavioral objectives, some of which were marked basic and the rest optional, and a copy of the hierarchy chart to guide him. Each objective is identified by both a Roman and an Arabic number; the Roman numeral refers to the chapter in the basic text to which the objective is related; the Arabic number identifies the objective in relation to the others within the same chapter. If a letter L precedes the Roman numeral, the objective is one which can only be demonstrated in the laboratory. The objectives whose numbers are enclosed in rectangles are basic and should be achieved in turn by all students. The arrows are included to guide the student in planning his study. For example, the student may begin with objective I-4, I-2 or I-12, but he should not attempt objective LII-11 until he has completed each of the three prerequisite sequences which lead to it: I-2, LI-3; I-4, I-7, LI-9; and I-12, LII-7. In each of these sequences one or more alternate pathways which include optional objectives are provided for students who

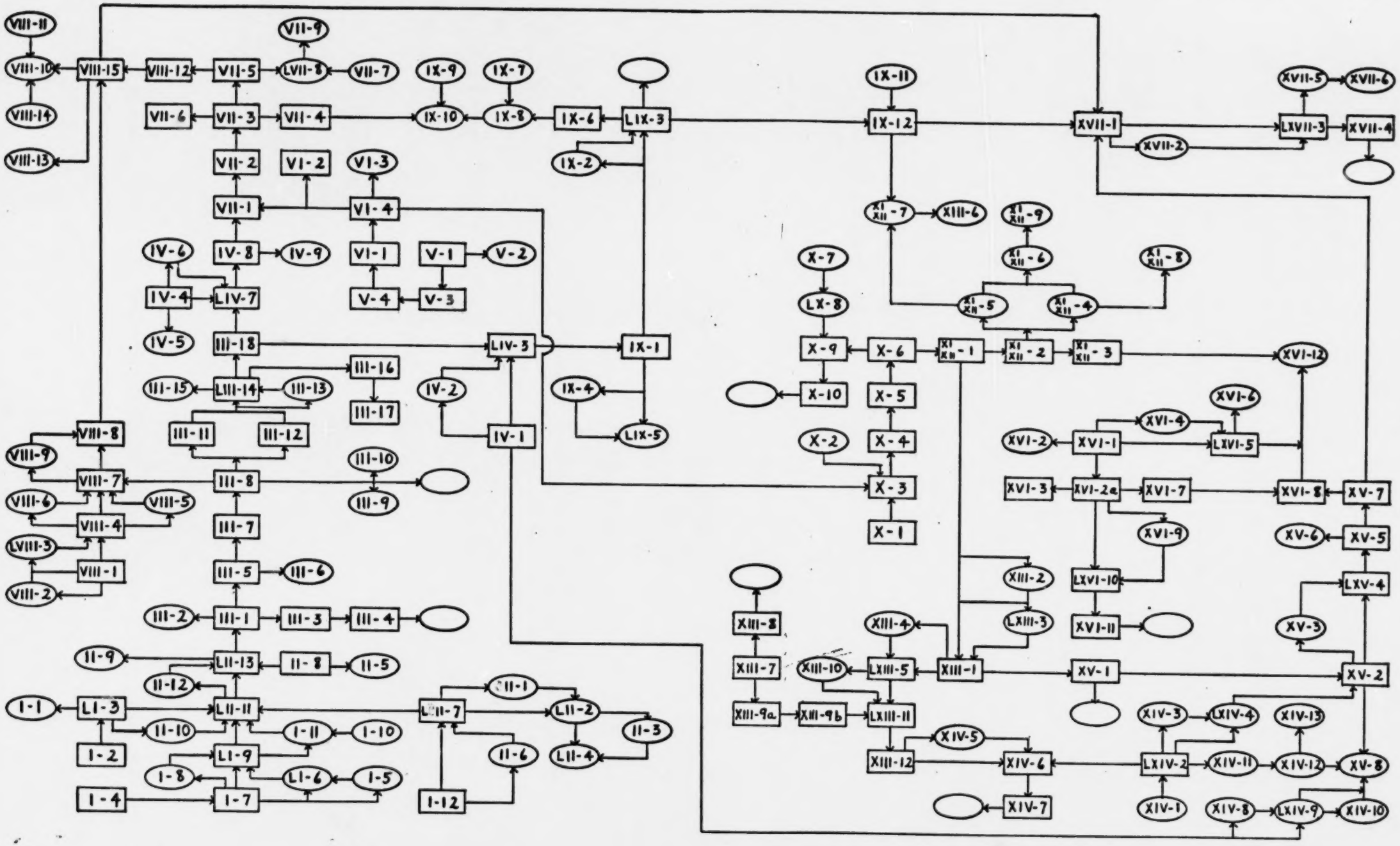

Figure 1. Each of the chemistry behavioral objectives in this hierarchy is represented by either a rectangle or an ellipse. The location of each objective in the hierarchy is based upon a judgment of the necessary prerequisites. The basic course is described by the objectives represented by rectangles. Each optional objective is represented by an ellipse; an empty ellipse indicates that the student should develop his own objective. Arrows are used to guide the students through the hierarchy from one basic objective to the next in sequence. Alternate pathways are provided for students who wish to follow sequences which include optional objectives.

wish to follow them. Some pathways terminate in empty ellipses to indicate to the student who wishes to do more that he is not restricted to the achievement of the designated basic or optional objectives, but is encouraged to investigate topics of special interest to him. No restraints are put on a student's efforts to study areas of particular interest to him as long as he achieves the basic objectives of the course. Finally, the independent study program provides a mechanism for an individualized chemistry course--a custom-tailored program is possible for each student--that was hoped for when the program was initially planned.

The independent study program now specifies a basic set of objectives to be achieved, provides for individualization through optional objectives and permits each student to learn at a pace geared to his own particular talents. But the assumption that students will make the best use of their time and pace themselves in line with their potential has not been supported in practice. Minimum acceptable standards of performance must be established. If the time that a student can spend in achieving the basic set of objectives were not fixed, the student could be evaluated on the quality of his performance and given a letter grade and credit for the course whenever he has achieved all of the objectives, or his performance could be evaluated as acceptable or not acceptable (pass-fail) and given credit for the course whenever he has demonstrated an acceptable level of performance for all of the objectives. In either case, a student would never fail. However, although a student would never fail, he would not receive any credit until he had achieved all of the objectives of

the course. As an alternative, if the time that a student can spend in a course is fixed, as in a school year, the student could be given a fractional credit equivalent to the fraction of basic objectives he had achieved at the end of the school year.

Since neither of the preceding procedures for evaluating students' performances could be put into effect in our school system without major changes in organization and policy, an alternate procedure had to be designed that could operate compatibly within the school system as it is.

Grades and Performance

One of the major problems encountered in conducting an independent study program is that of evaluating and grading each student's performance. Commager (7) has said, "Grades themselves are of little importance, but standards are; imagine dispensing with standards in medicine or law. If the academy is to put the stamp of approval on students not on the basis of competence but of race, or of needs, or of compassion, then it can no longer maintain any standards at all." Our experience indicates that standards of acceptable performance must be specified to guide students even when dealing with self-motivated learners. Whether or not a person "believes" in grades is not really relevant; in most schools grades must be determined periodically. So the teacher must develop a grading system.

What are the characteristics of a good grading system for independent study students? The grading system should be designed so as to reflect to what extent a student has met the standards of the course. The following guidelines were established by the writer as a basis for developing a grading system.

1. The student should know what he will be expected to learn; how he will be graded (what the standards are); be able to determine his own grade at any time; and be given credit for the course only when he has learned what he was expected to learn.
2. Standards and expectations should be the same for all students in the same course (as listed on the school records) regardless of class or section assignment.
3. The grade should be based on what the student learned compared with what he was expected to learn as specified by the course objectives for all students.
4. Measures of how much and how well the student has learned should be included in the grade.
5. Evaluations of the quality of student performances should be reported on a numerical scale so as to permit an arithmetical computation of the grade. It is taken for granted that the specific evaluations will be based on subjective judgments by the mentor.

In our school system students are enrolled in each science course for 36 weeks. Report cards are issued every six weeks; consequently, an interim grade for each student must be determined six times. At any time independent study students will be found to differ in both the quantity and quality of the competencies they have acquired. If a grade were required only at the end of the school year, evaluation would be based on the standards established to receive credit for the course as a whole. Since a check is made on the progress of each student every six weeks, it follows that for each checkpoint interim

standards of achievement must be established with which the student may gauge his progress.

In order to establish a standard of performance for each succeeding checkpoint, the set of behavioral objectives was divided into six sequential subsets of basic and related optional objectives on the basis of independent estimates by the writer and two other chemistry teachers (6) of the number of days a "typical" student would need to achieve each basic objective. At each checkpoint the student's progress is evaluated in terms of how many of the basic objectives he was expected to achieve as of that date and on the quality of his performance. The number of basic objectives specified as the standard at each checkpoint includes all of those specified for each of the preceding checkpoints. Consequently, the student's interim grade will be cumulative and indicate his total performance to date. There appear to be no practical alternatives to cumulative interim grades for independent study programs which require the achievement of a set of interrelated and dependent behaviors within a fixed period of time.

How is the quality component of a student's performance determined? Each basic and optional objective has been assigned a numerical value based on a judgment of the relative significance and/or complexity of the competency to be acquired. Whenever a student decides he is ready to demonstrate that he can do what the objective states he should be able to do, his performance is evaluated on a scale from zero to the maximum value assigned to the objective. For example, if an objective is assigned a maximum numerical value of 12, the student may receive

any score from zero to 12 depending of the quality of his performance as judged by his mentor. If a performance is considered to be of acceptable quality, it is given a score equivalent to 70 per cent or more of the maximum value depending on its quality. Students who do not perform acceptably, continue their study and try again when they believe they can. Students who make two or more attempts before demonstrating an acceptable performance are credited with the average of the scores obtained on all attempts. Students' records will show the number of points scored over the number of points possible for each objective achieved. A percentage grade indicating the quality of each student's performance is obtainable easily at any time by dividing the sum of the student's scores by the sum of the scores possible for all of the objectives he has achieved.

How is the quantity component of a student's performance determined? The student knows which and how many basic objectives he is expected to achieve on or before the date of each checkpoint. The percentage grade indicating the quantity component of his performance can be calculated easily for each checkpoint by dividing the number of basic objectives he has achieved by the number of basic objectives he was expected to achieve.

The optional objectives achieved by a student are included in determining the quality and quantity component of the student's performance at any checkpoint if the student has achieved all of the basic objectives he was expected to achieve. In that event, no distinction is made between the basic and optional objectives achieved in calculating grades. However, the percentage quantity grade will always be greater than 100% for

the student who achieves optional objectives because the total number of basic and optional objectives achieved is divided only by the number of basic objectives he was expected to achieve. In this way the student who can and does do more is credited for his accomplishments.

Finally, the student's percentage grade in the course at any specified checkpoint is obtained by taking the average of the percentage quality and quantity grades. In line with school policy, a scale from 100 to 70 divided into four equal parts is used to convert the percentage grade to an A, B, C or D respectively. An average percentage grade less than 70 indicates an unacceptable level of performance and is reported as an E.

Experience with students forced us to introduce one restraint into the grading system. A few students motivated simply by a desire for high grades chose to attempt the achievement of as many as possible of the optional objectives in addition to the basic objectives at minimum quality performance standards. As a consequence, it was possible for a student with even an unacceptable percentage quality grade to receive an A when his quantity and quality percentage grades were averaged. The quantity and quality aspects of a student's achievement are both important, but in my judgment, and in the judgment of most of my students to my surprise and pleasure, learning to do something well is more desirable than learning to do many things at minimal acceptable levels of competence. The loophole was closed simply by stating that the letter grade at any checkpoint may not be more than one level higher than the quality grade for that checkpoint. For example, if the percentage quality grade is

equivalent to a C on the conversion scale, the letter grade the student will receive on his report card cannot be higher than a B, although the student's percentage grade obtained by averaging the quality and quantity percentages would indicate that it should be.

This may seem to be much to do about a relatively trivial matter--grades. That is just the point that should be made. Let the standards and assessment procedures be known so the student can concentrate on his education with full knowledge of the expectations for him. Whether or not a student is motivated by grades alone or by a real love for learning is not as important as that he learn. If he does, he may also learn that knowing is its own reward.

The system works easily and automatically. Once implemented, it serves constantly and unobtrusively as a guide to the student on what needs to be learned and on the standards of acceptable performance. The system also provides a mechanism for evaluating and crediting differences in individual achievements. But, most importantly, it emphasizes standards of achievement. As of this writing, with four months of the school year completed, approximately 25 per cent of the students are from one to two months ahead of schedule. Many will complete the course before the end of the school year.

Know You Know Index

The independent study student plans and directs his own activities for learning. Eventually, for each objective the student must decide for himself that he is able to do what the objective states he should be able to do and asks that he be

permitted to demonstrate that he can. Many students find it quite difficult to make these decisions; they cannot decide when they know or do not know.

In my opinion an educated person knows what he knows and what he does not know. Socrates (8) in describing one of his accusers said, "He knows nothing, and thinks that he knows; I neither know nor think that I know. In this latter particular, then, I seem to have slightly the advantage of him." Learning can only occur when a person is aware of what he knows and does not know. Only then can he identify his needs and organize his resources to accomplish the learning tasks. Expressed as a behavioral objective this general education goal would read: the independent study chemistry student while engaged in activities designed by him to achieve a particular competency should be able to state, when asked, what he knows, demonstrate what he can do and identify what he still needs to know and/or learn to do.

The opportunity to exercise this judgment and to generate a rationale for doing so is not generally available to students. Teachers typically decide when their students know or do not know. The student's role is a passive one. But students, as part of their education, should acquire the ability to consider the information they receive, in whatever form or from whatever source, and organize it into meaningful relationships. They should also learn to evaluate what they have learned and judge the extent of their understanding.

Is it possible to obtain an indicator of the student's ability to make decisions of this kind for himself--a know you

know index, so to speak? As a matter of fact, this is quite easy to do. In this program, the student decides when he is ready to demonstrate that he can do what the objective states he should be able to do. If he does so successfully, he has demonstrated not only that he has achieved the objective but that he knew that he would be able to demonstrate that he had. He knew that he knew! If, however, he does not succeed, he also demonstrates that he did not know that he did not know! He returns to the task of acquiring the competency. The cycle is repeated until the student demonstrates that he has achieved the objective and, concomitantly that he knew that he knew. Since a record is kept of the number of times a student attempts to demonstrate the achievement of each objective, his know you know index, reflecting his ability to decide when he has acquired a particular competency, can be calculated at each checkpoint by dividing the number of basic objectives he achieved by the number of times he attempted to demonstrate that he could do what each of the objectives stated he should be able to do. This is equivalent to dividing the number of right decisions (he knew he knew) by the total number of right and wrong decisions (knew he knew plus did not know he did not know). For example, a student who made 20 attempts in achieving 15 objectives would have a know you know index of 0.75.

The know you know index for each student is calculated at each checkpoint. It has made quite an impression on the students--they talk about their KYK indices. Students have become more critical and discerning about their thoughts and activities. A low KYK index may mean that a person needs to be

more analytical, precise, thorough and, perhaps, honest with himself. As a measure of the student's awareness of his state of knowing, the KYK index is reported in any discussion of a student's progress. There has not been enough time to evaluate its full meaning, but a student's KYK index may prove to be a most reliable indicator of the state of his education. Surprisingly, although the KYK index has no direct bearing in the determination of students' grades, they are interested in improving it. Just having it seems to have sparked a greater interest in learning how to learn. This interest should result in higher KYK indices as each student learns better how to know when he knows.

Achievement Compared

The independent study program has been based from the beginning on the assumption that students can learn on their own whatever they are expected to learn in conventionally taught classes. To establish a basis for comparing their achievement, the independent study, accelerated and regular students in each of the three years took the same examinations. The means for each group on the semester and final examinations are summarized in Table 1. The decision was made to compare the achievement of the independent study students with that of the accelerated students since their test scores were similar. To obtain a measure of the scholastic aptitudes represented by the independent study and accelerated students, the Differential Aptitude Tests of Abstract Reasoning (DAT-AR) and Numerical Ability (DAT-NA) were administered each year. The means for each group are presented in Table 1. Since random sampling procedures were not

employed in the selection of either the independent study or accelerated groups, a nonparametric method requiring no assumptions other than that the populations being sampled are continuous--specifically, the U-test--was employed to test the hypothesis that both samples came from the same population (9).

The calculated z values obtained by applying the U-test to the DAT-AR, DAT-NA and final exam scores for each sample in each year are summarized in Table 2. Using a level of significance of 0.05 the null hypothesis that the independent study and accelerated students were from equal populations, particularly with equal means in scholastic ability as measured by the DAT-AR and DAT-NA, cannot be rejected for the 1966-67 and 1967-68 samples but must be rejected for the 1968-69 samples--the scholastic ability of independent study students is significantly greater than that of the accelerated students in 1968-69. Using a level of significance of 0.05 the null hypothesis that the independent study and accelerated students are from equal populations, particularly with equal means in achievement as measured by the final examinations, cannot be rejected for the 1966-67 samples but must be rejected for the 1967-68 and 1968-69 samples--the achievement of the independent study students is significantly greater than that of the accelerated students in 1967-68 and in 1968-69. In other words, the independent study and accelerated students in 1966-67 do not differ significantly in either their initial ability or in their achievement; in 1967-68 they do not differ significantly in their initial ability but do differ significantly in their achievement; and in 1968-69 they differ significantly both in their initial ability and in their achievement. The independent study students have learned on their own whatever was expected of them, and more.

Table 2. Comparison of z Values* With Critical Values: Chemistry Independent Study vs. Accelerated Students

	1966-67	1967-68	1968-69	P <0.05
DAT-AR	-0.18	-0.70	2.61	<-1.96 or >1.96
DAT-NA	-0.50	1.67	2.06	<-1.96 or >1.96
Final Exam	1.71	2.36	4.17	<-1.96 or >1.96

* Obtained from application of the U-test to the data.

At the end of the first year of the program, a study of the comparative achievement of independent study and accelerated students on the chapter, semester and final examinations revealed that the means of the accelerated classes exceeded that of the independent study classes at the beginning of the year but that the reverse was true toward the end of the school year (1). When the differences in means of the two groups on the semester and final examinations were compared, the analysis revealed a difference (1 percentage point) in favor of the accelerated class on the semester examination but a difference (9 percentage points) in favor of the independent study group on the final examination. The semester and final examinations are designed to evaluate the learning expected to occur throughout the first half of the year and the whole year respectively and stress the major understandings and basic threads which interweave knowledge in chemistry. The question was asked: Do the data mean that after a year of study the independent study students, who are learning on their own, are better able than the accelerated students, who are being taught, to achieve, retain and place in perspective the

processes, observations, generalizations and hypotheses which constitute chemistry? Now, two years later, the question is even more pertinent.

The differences between means for independent study and accelerated students on each of the semester and final examinations for each of the preceding three years are presented in Figure 2. The means of the independent study classes always exceeded those of the accelerated classes on the final examinations. The difference between means on the final examination is greater than the difference between means on the semester examination in each of the three years; the consistency of the trend is striking. The difference between what independent study students learn compared with what conventionally taught students learn increases with time. The results strongly suggest that independent study students are making effective strides not only in what they learn but also in learning how to learn.

Development of the Program to Continue

The hope expressed in the beginning of this paper has been realized--a viable independent study program in chemistry is in operation and functioning well. Since no insuperable difficulties were encountered this year when the enrollment was doubled and an inexperienced mentor added to the program, plans are being made to expand it further. The procedure of selecting students will be changed to permit any student to enroll in the program who wishes to do so. The Independent Study Science Program will be modified to permit students to enroll in a new science course upon completing the requirements of the preceding course in the sequence. Students will spend more or, hopefully, less than one year in any course, and they will begin a new course at any time

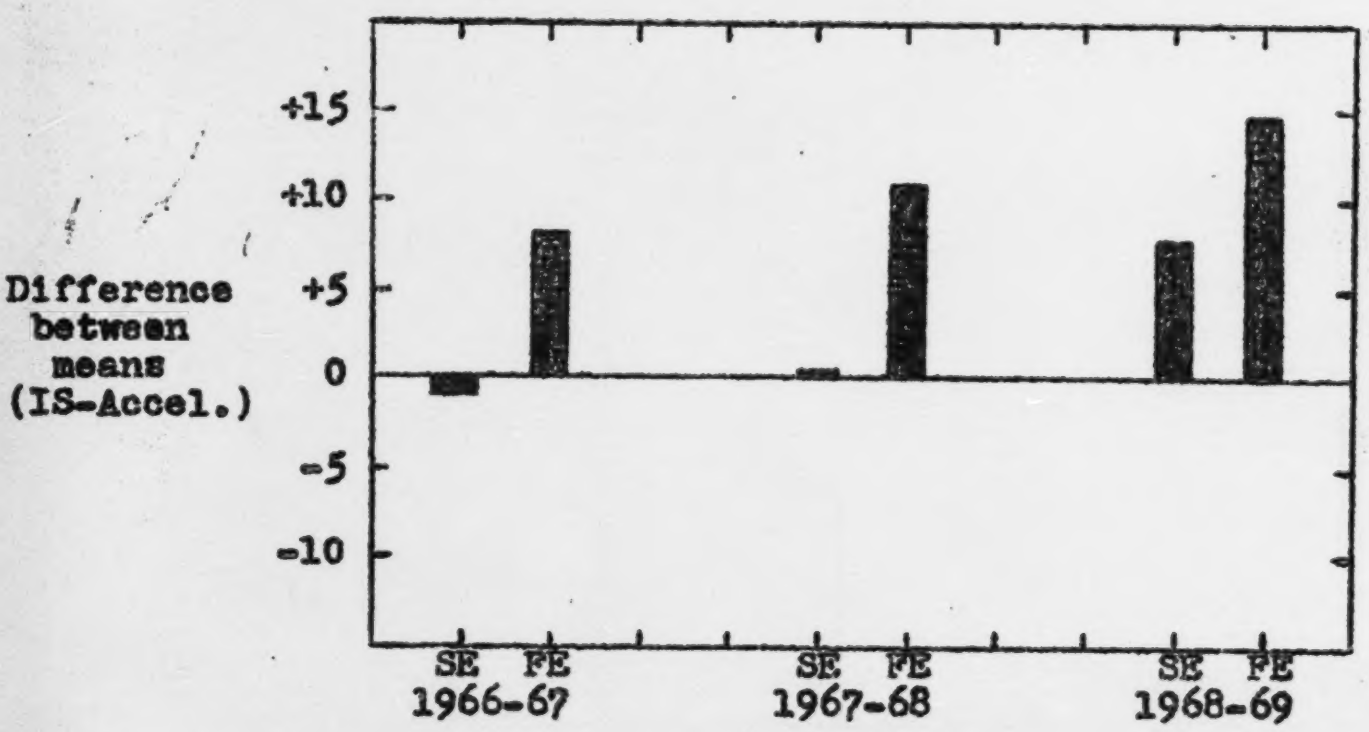

Figure 2. Differences between examination means of 1966-67, 1967-68 and 1968-69 independent study and accelerated college preparatory chemistry classes expressed by the amount the independent study class mean was more or less than the accelerated class mean on each examination. Results on the semester and final examinations for each of the three years are compared. The semester examination (SE) covered the work of the first half of the school year (semester) and the final examination (FE) covered the work of the whole school year. The same examinations were taken by both classes each year. The same final examination was given in each of the three years.

during the school year. Since the program will be subjected to continuous evaluation, further changes in the format and operation are anticipated.

Much time has been spent in trying to share the experience of developing this program. The purpose has been to describe the problems encountered and the solutions formulated to meet them. There is a sense of satisfaction in knowing that what could have failed was made to succeed. But what pleases me most is the learning environment which my students and I now share.

References and Notes

1. DeRose, J. V., "The Independent Study Science Program at Marple Newtown Senior High School." The Science Teacher, 35:48, May 1968.

2. "Jean Piaget: Mapping the Growing Mind." Time, 94:24, December 12, 1969, pp. 61-62.

3. Mager, R. F., Preparing Instructional Objectives, Fearon Publishers, San Francisco, California, 1962.

4. Chemical Bond Approach Project, Chemical Systems, Webster Division, McGraw-Hill Book Company, Manchester, Missouri, 1964. Although the accompanying laboratory guide, Investigating Chemical Systems, is not distributed to students, it was used as resource in writing behavioral objectives to be demonstrated in the laboratory. Each student also receives a copy of Sienko, M. J. and Plane, R. A., Chemistry, Third Edition, McGraw-Hill Book Co., 1966, and a list of supplementary references pertinent to each topic.

5. DeRose, J. V., "New Directions for Chemical Education in High Schools," The 1969 STAR Awards, NEA Publications, Inc., Washington, D. C., 1969.

6. The assistance of Paul Billett and John Metka is gratefully acknowledged. Mr. Metka now serves as the other mentor, and Mr. Billett has from the beginning substituted for me as mentor whenever I needed to be away.

7. Commager, H. S., "Universities Can and Must be Saved from Destruction." The Philadelphia Inquirer, September 7, 1969, Section 7, p. 1.

8. Plato, The Dialogues of Plato, translated by Benjamin Jewett, Great Books of the Western World, Encyclopaedia Britannica, Inc., Chicago, Illinois, 1952, pp. 202-203.

9. Freund, J. E., Modern Elementary Statistics, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1960.